Aviation Weather Communications Requirements, Technology, and Solutions

AvSP Program Review
Hampton, VA
May 23 - 25, 2000

NASA John H. Glenn Research Center
at
Lewis Field

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Outline

- Project Overview
- Current / Near Term In-Flight Weather Products/Systems
- Aviation Weather ~ A Pilot's Paradigm
- Resulting Human Predicaments
- Proposed Direction
- Non-aviation Communications - Potential Wx Solutions
- Conclusions / Recommendations

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- Non-aviation Communication Wx Solutions
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Roger Herron - LM Aero

Program Summary

- **Title:** *Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems*
- **Challenge:** *"Leverage commercial and public sector communications infrastructure investments / activities to ensure efficient implementation of new tactical and strategic weather tools in the cockpit." - SOW*
- **Team:**
  - **NASA GLENN:** Gus Martzaklis (WINCOMM Element Manager), Jerry Chomos (Task Manager)
  - **LM Aero:** Jack Ball, E.T. Nozawa, Roger Herron
  - **ACI:** Ed Thomas, Dave Witchey
- **Time Frame:**
  - **Phase I (Wx Comm Reqmts)** **Sept 98 - March 1999**
  - **Phase II (Wx Comm Solutions)** **July 99 - March 2000**

Questions to Answer

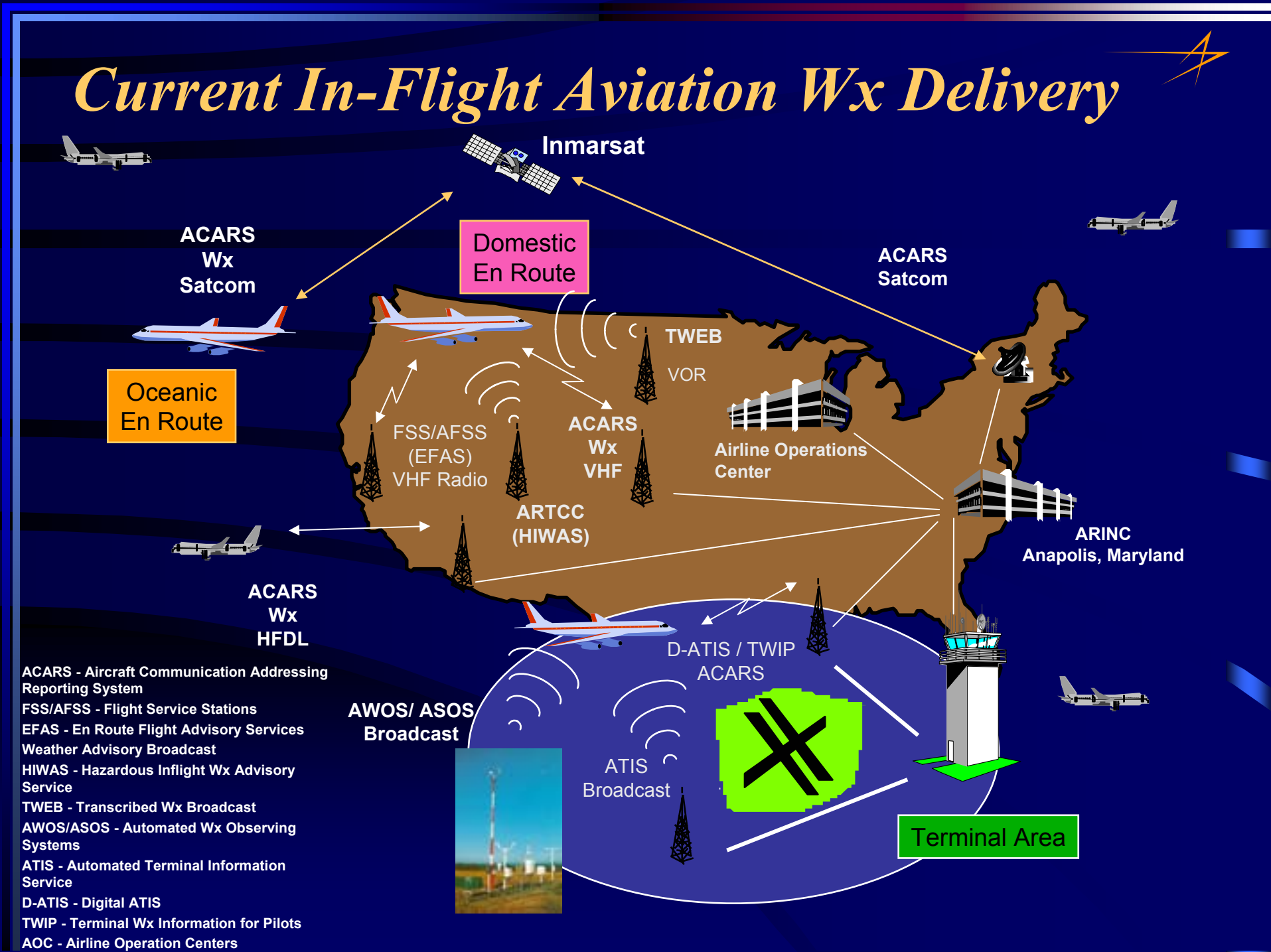
What weather information is needed in the cockpit to reduce weather related accidents and what communication capability is needed to get it there?

Will future aviation communication systems meet the requirements and what other communication systems might be used for aviation weather?

What communications research needs to be done and what technologies need to be developed to get safety related weather information to the cockpit?

Ideas should be considered from the perspective of "how things could be" rather than "how things are"

Current In-Flight Aviation Wx Delivery

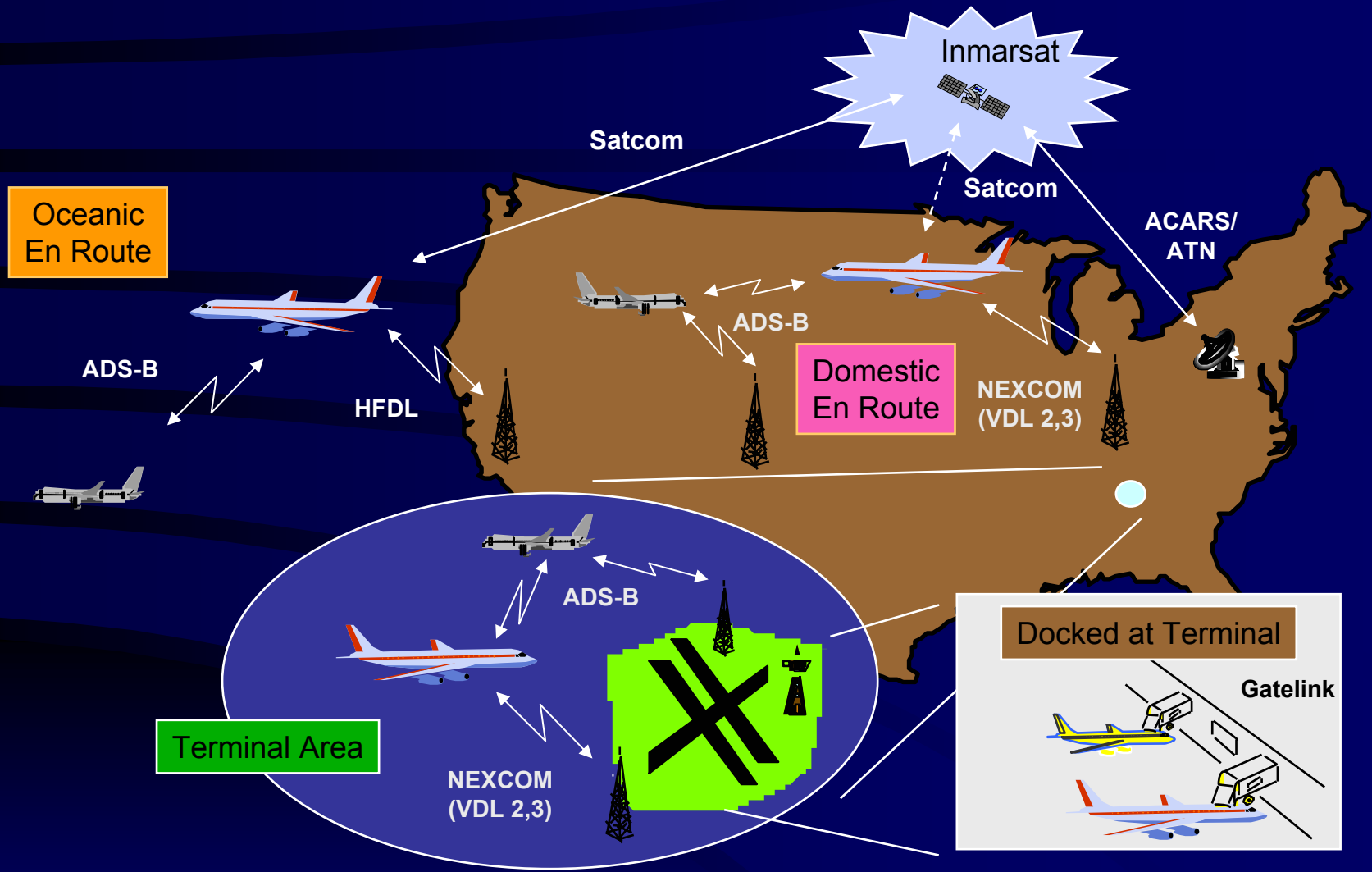


ACARS - Aircraft Communication Addressing Reporting System
FSS/AFSS - Flight Service Stations
EFAS - En Route Flight Advisory Services
Weather Advisory Broadcast
HIWAS - Hazardous Inflight Wx Advisory Service
TWEB - Transcribed Wx Broadcast
AWOS/ASOS - Automated Wx Observing Systems
ATIS - Automated Terminal Information Service
D-ATIS - Digital ATIS
TWIP - Terminal Wx Information for Pilots
AOC - Airline Operation Centers

Current / Near Term In-Flight Wx Products

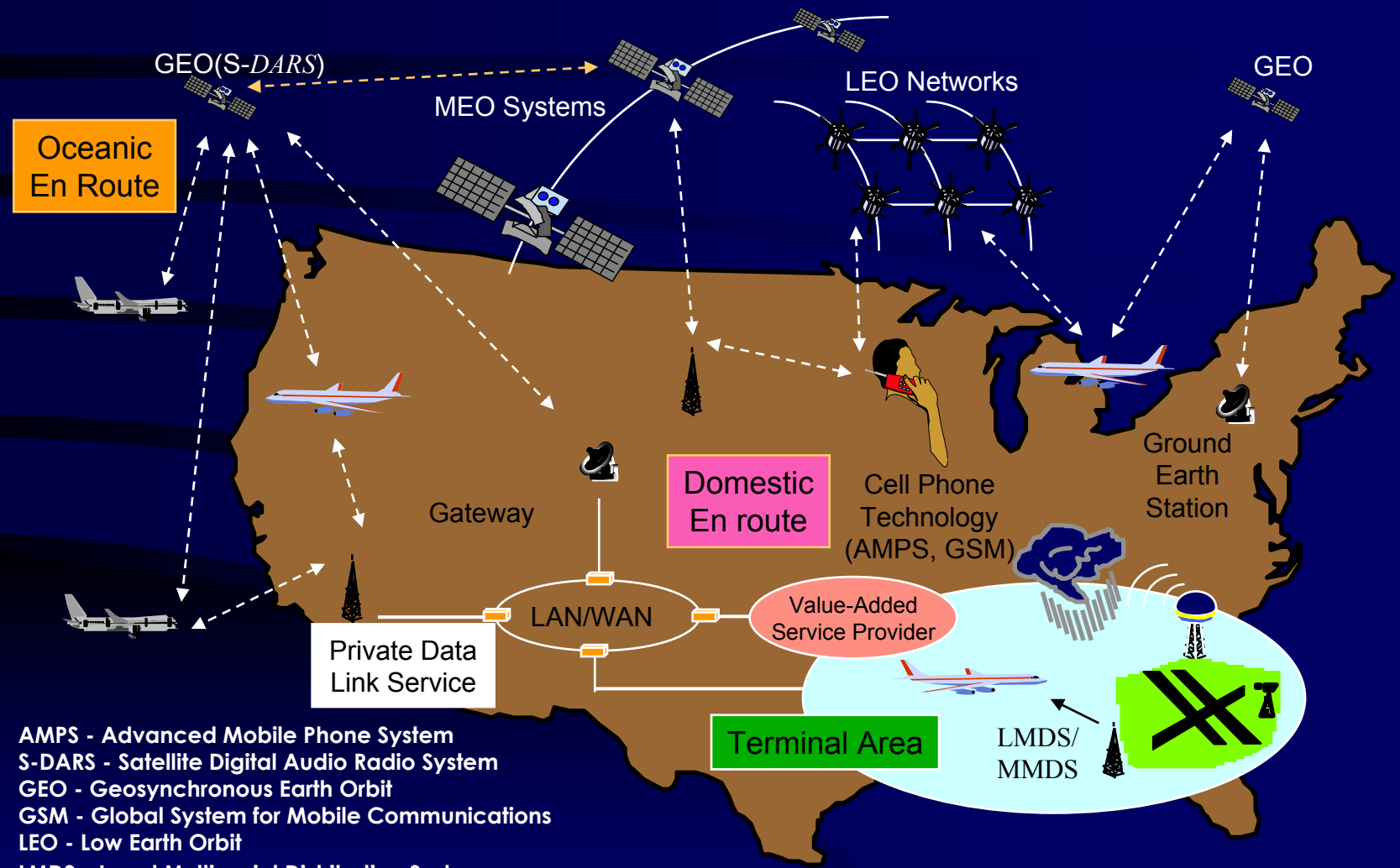
- **Current Wx Products Available in the Cockpit**
  - Terminal Area Specific: **METAR, TAF, ATIS, D-ATIS**
  - Domestic En Route: **Area Forecast**, **Severe Wx Forecast Alerts, AIRMET, SIGMET, Convective SIGMET and Center Wx Advisory, Winds Aloft, PIREP**
  - Oceanic En route: **International SIGMET**
- **Current In-flight Wx Delivery Systems**
  - Voice Format Request / Reply: **FSS, AFSS, EFAS**
  - Voice Broadcasts: **ARTCC, HIWAS, TWEB, AWOS, ASOS, ATIS**
  - Text Format Request / Reply: **ACARS**
- **Near Term Addition- Flight Information Services Data Link (FIS DL)**
  - Text Format Broadcast: **Complement, not replace, existing voice communications.**
  - FAA: **Provide broadcast data link (four 25 kHz VHF channels)**
  - Commercial Vendors: **Provide standard (free) and value added (fee based) weather products.**
  - Standard Products: **METAR, TAF, SIGMET, AIRMET, Pilot Reports (PIREPs) and Aviation Watches (AWW),** Potential Value-added Products: **NEXRAD graphics, satellite imagery, icing maps, turbulence maps, winds aloft**
- **Future Additions - Based on On-going Research**
  - **Will include:** more pictures, graphics, and gridded information with associated decision support - highly bandwidth intensive

Potential Aviation Comm Solutions



ADS-B Automatic Dependent Surveillance - Broadcast
ACARS: Aircraft Communications Addressing and Reporting System
ATN: Aeronautical Telecommunication Network
HFDL: High Frequency Data Link
VDL: VHF Data Link

Potential Non-Aviation Comm Solutions



AMPS - Advanced Mobile Phone System
S-DARS - Satellite Digital Audio Radio System
GEO - Geosynchronous Earth Orbit
GSM - Global System for Mobile Communications
LEO - Low Earth Orbit
LMDS - Local Multi-point Distribution System
MEO - Medium Earth Orbit
MMDS - Multi-channel, Multi-point Distribution System

Outline

David Witchey - ACI

- Aviation Weather ~ A Pilot's Paradigm
- Resulting Human Predicaments
- Proposed Direction
- Non-aviation Communication Wx Solutions

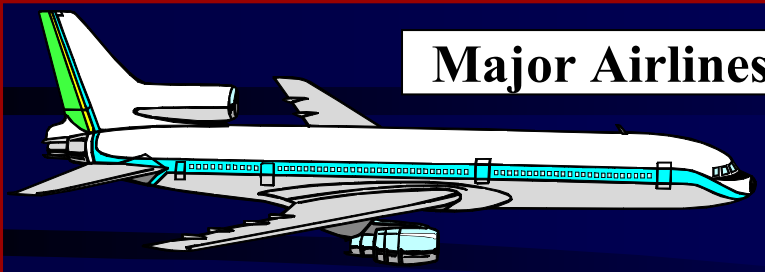
Background

- **Purpose:**
  - *"Evaluate and determine the feasibility of using the existing aviation communications infrastructure for supporting future weather tool implementation." - SOW*

A PILOT'S PARADIGM

- User considerations
- How we use weather
- A close look at the paradigm
- Where we use weather
- Bandwidth implications
- Product implications

Aviation User Considerations

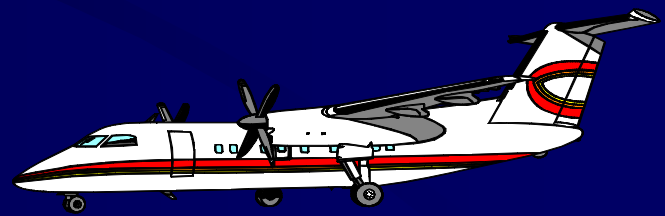


Major Airlines

- Significant ground infrastructure
- Cockpit upgrades resisted
- Forward fit preferred
- Older fleets may be done in conjunction with cabin / entertainment upgrades

Other Scheduled Carriers

- More time in the weather (lower altitudes and slower speeds)
- Graphical weather may be more valuable
- Some new Regional Jets being delivered with graphical weather



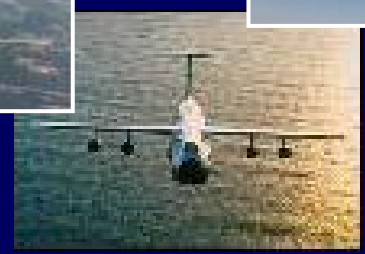
Aviation User Considerations

General Aviation

- Lower altitudes
- Icing and turbulence ~ increased threat
- Highly price sensitive, politically powerful
- Small percentage ~ Wx radar or stormscope
- Regional, broadcast weather valuable

Military Aviation

- Military transport needs ~ similar to airlines
- May share sources and suppliers
- Dedicated systems for special applications



How We Use Weather Information

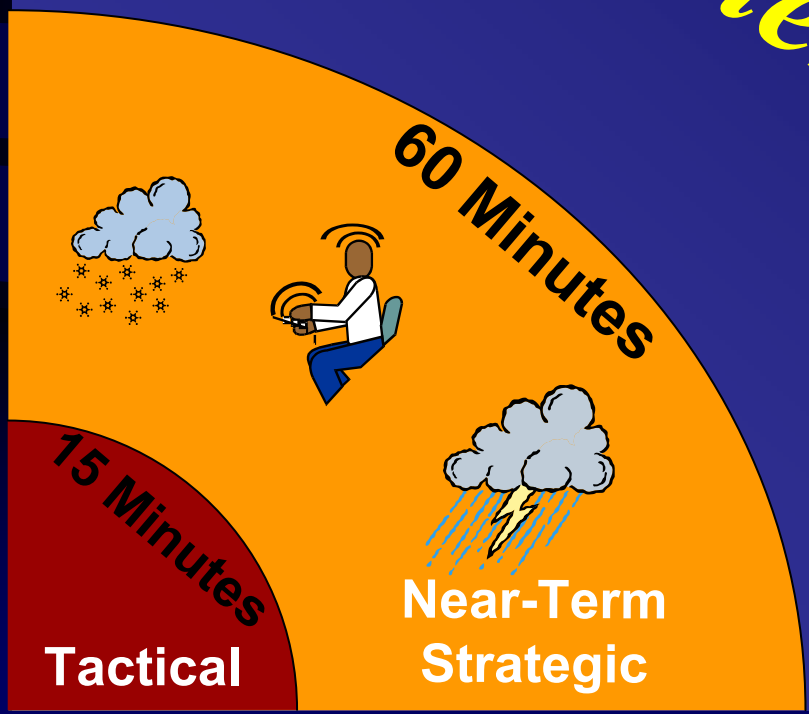
- **Strategic**
- **Tactical**

General Implications

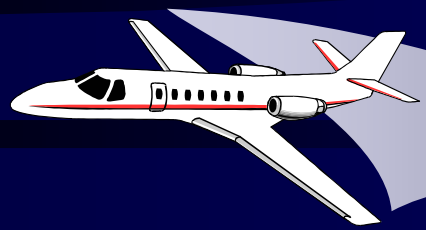
- **Strategic**
  - Planning Mode
  - Routing
  - Avoidance
- **Tactical**
  - Execution Mode
  - Maneuvering
  - Penetration

A Closer Look...

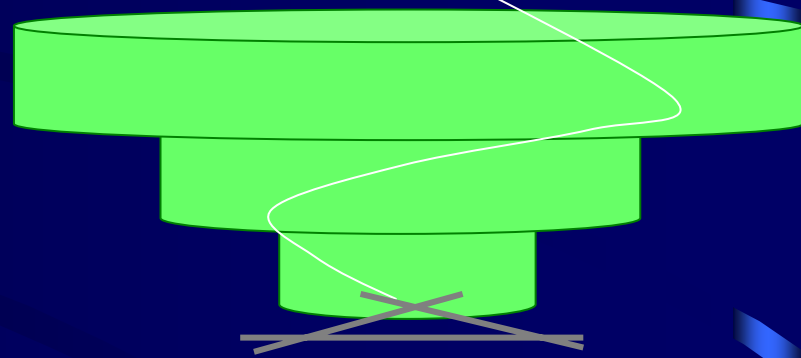
Three Weather Decision Arenas



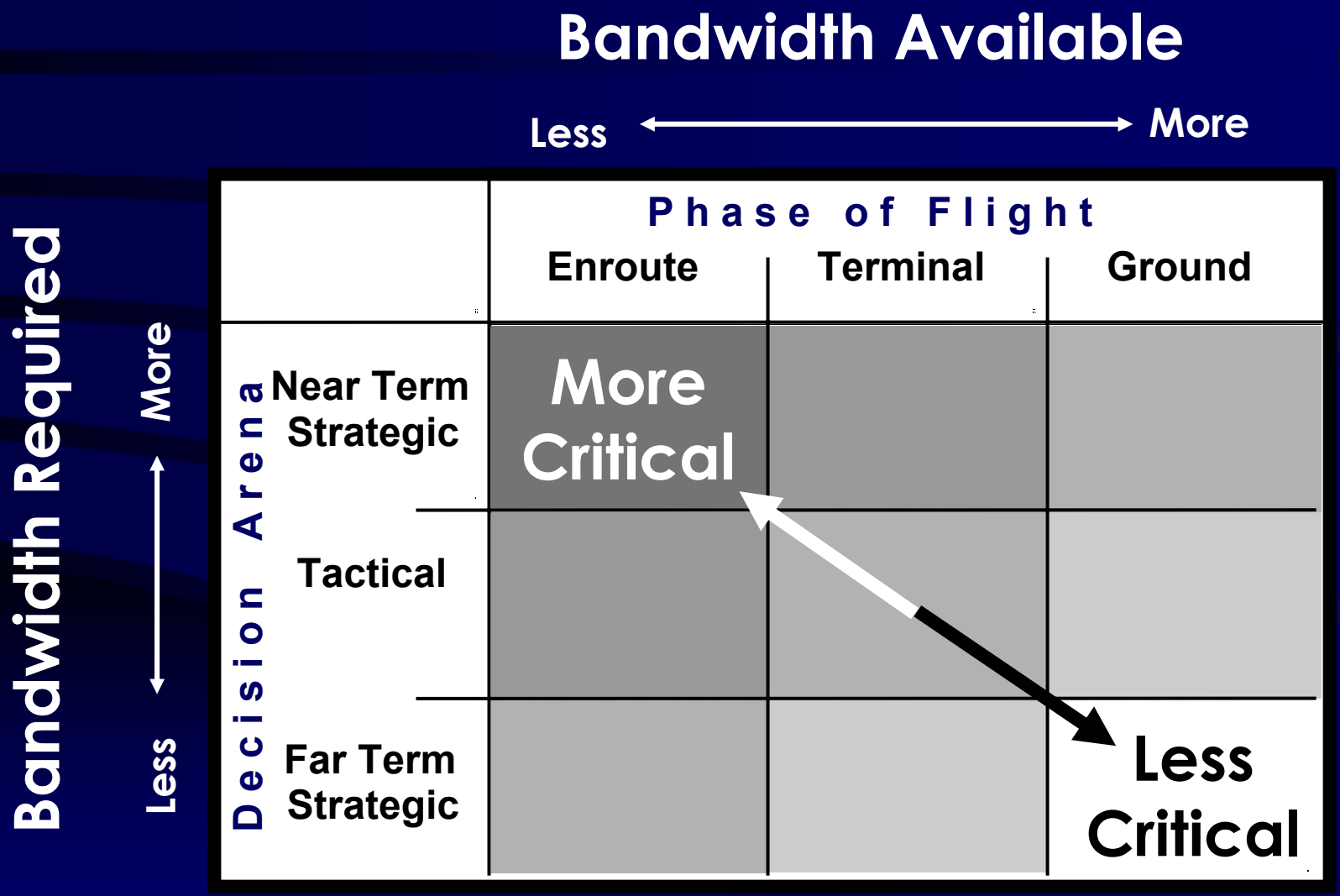
Where We Use Weather Information



- **Ground**
- **Terminal**
- **Enroute**



Bandwidth Concerns



Specific Implications

- **Three General Levels of Interest**
- **Two Sets of Strategic Products?**
  - Far Term
  - Near Term
- **Kinds of Products**

For Example...

- **General hazard**:
  - Integrates all known “threats”
- **Discrete products**:
  - Turbulence, Convection, Icing / Flight Conditions, Winds/Temperature, Surface Conditions, etc.
- **General areas of regard**
  - Near-term Strategic, Far-term Strategic, Tactical
- **Fidelity Needed**:
  - Near-term Strategic, Far-term Strategic, Tactical
- **Backup Strategic:**
  - General Imagery

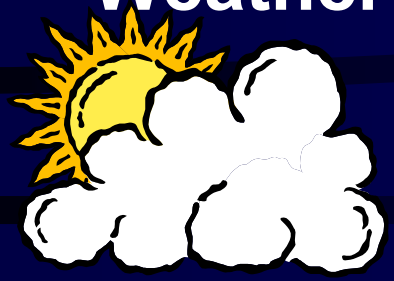
A HUMAN'S PREDICAMENT

- **What is weather to a pilot?**
- **The bottleneck on the flightdeck**
- **Information, not Data!**

What is Weather… Really?

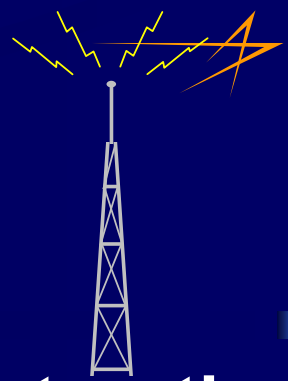
"Threats" include

Weather



Passenger Perception/Actions

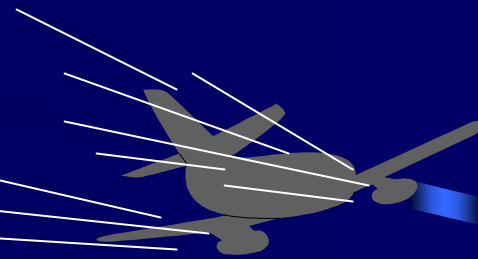
Terrain



Obstructions

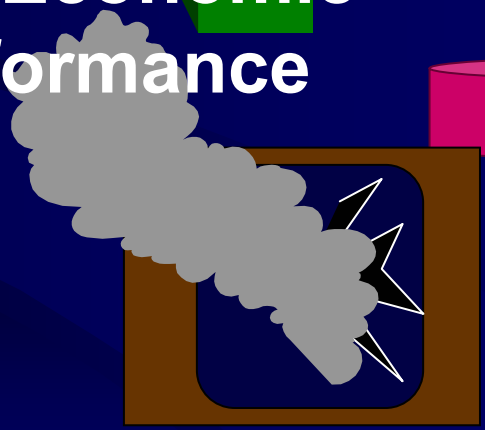
Traffic

Poor Economic Performance



Environment

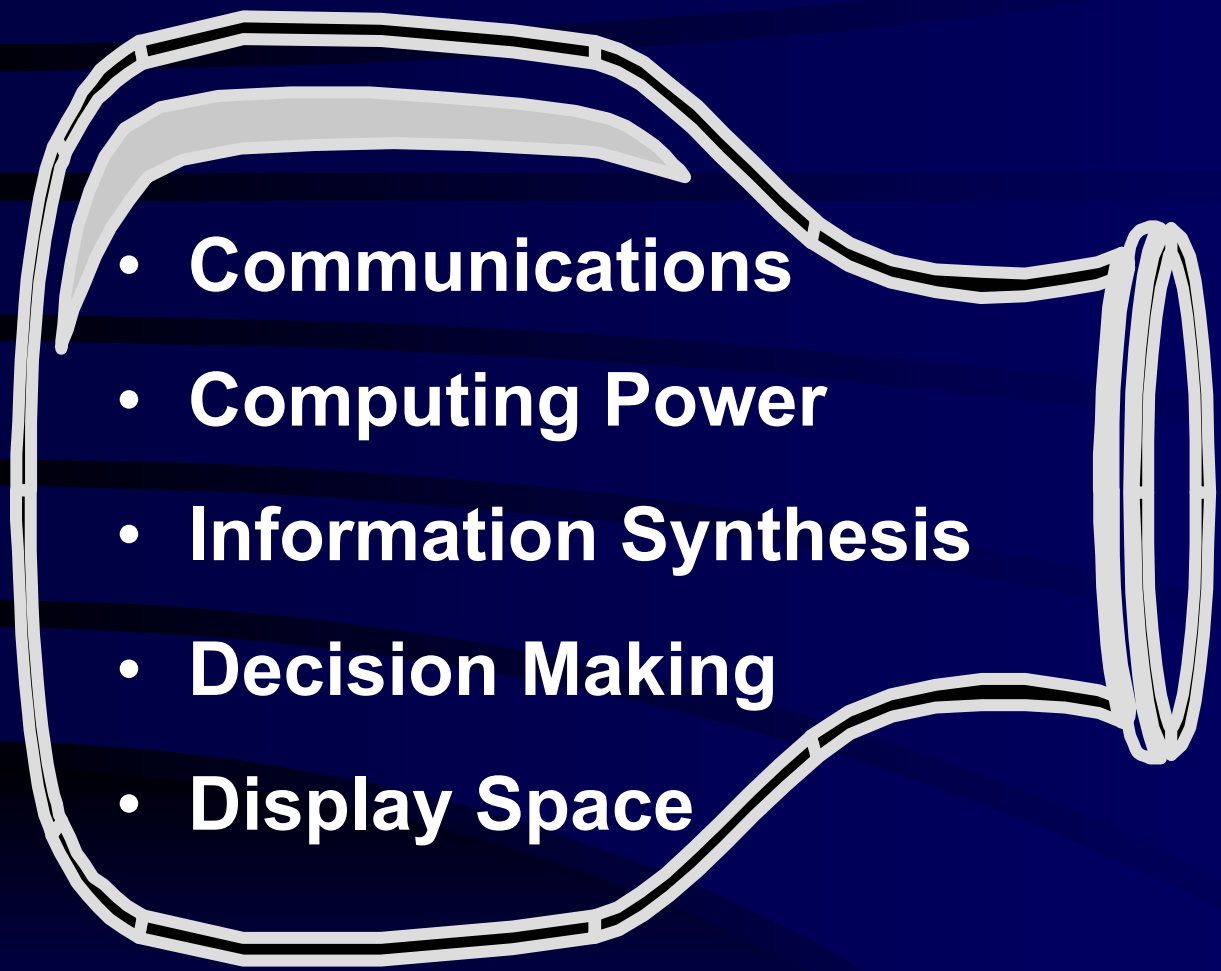
"Liability Gap"



Equipment Failures

Airspace

A Bottlenecked Flight Deck



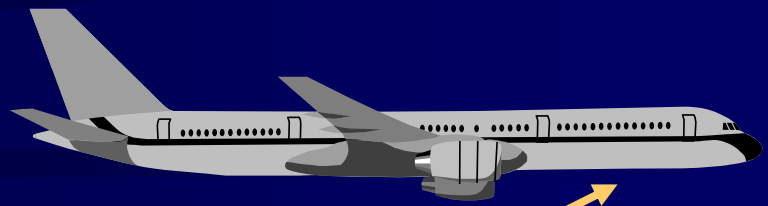
- Communications
- Computing Power
- Information Synthesis
- Decision Making
- Display Space

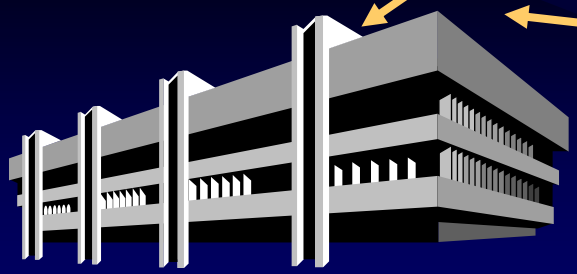
I Don't Need More DATA!

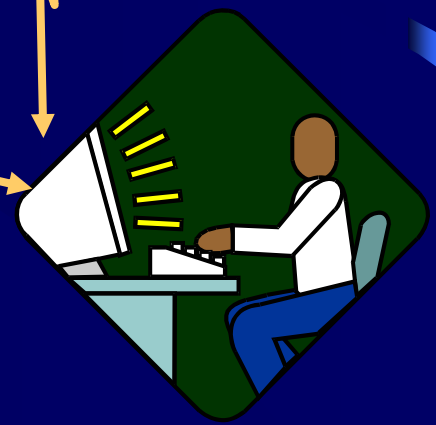
- I Need Information!
- Contextualized
- Decision Aids

Who is "Smarter"?

- **Airplane?**
- **AOC?**
- **ATM?**



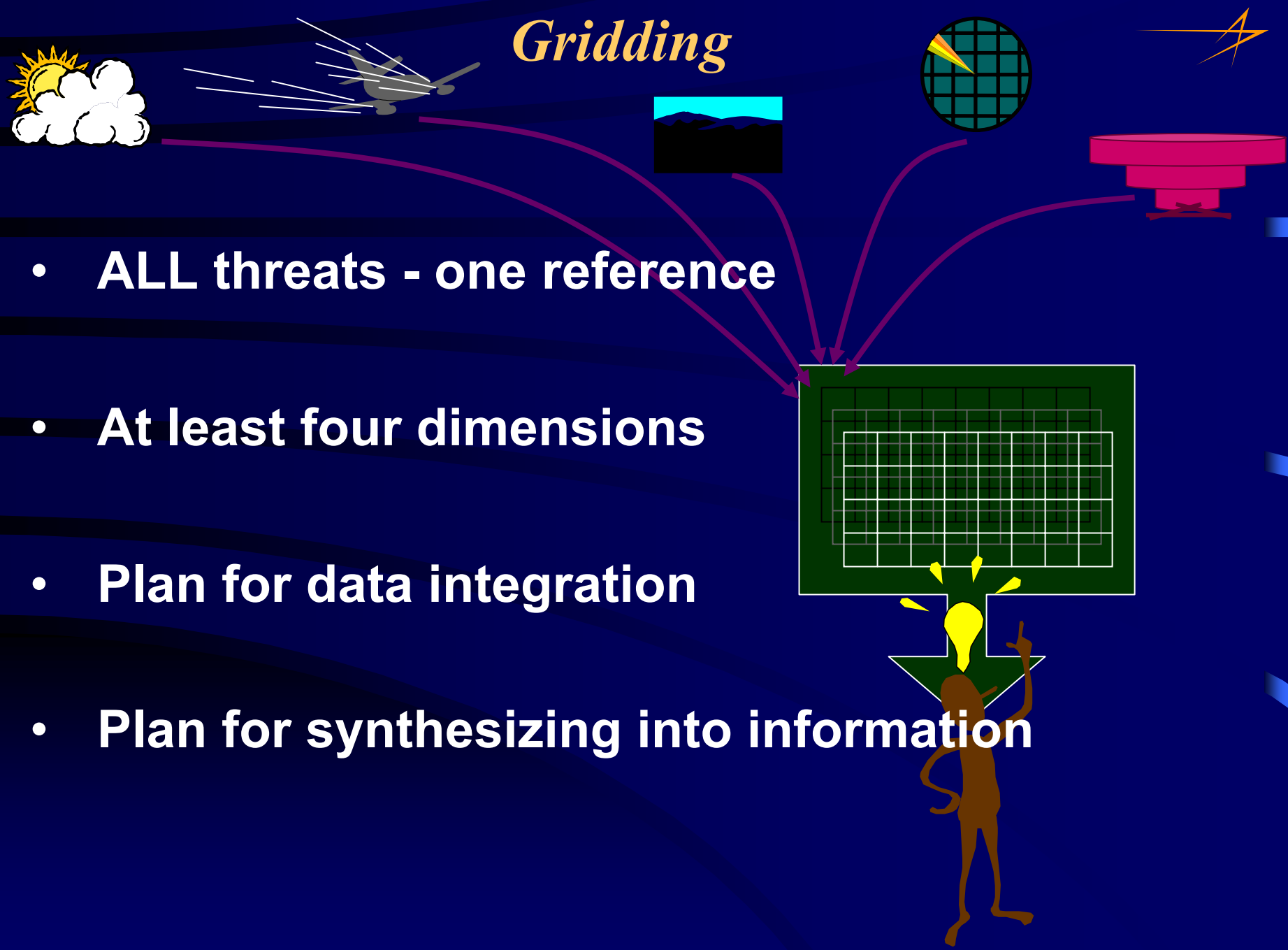




AN ENGINEER'S PROPOSAL

- **Gridding**
- **Indexing**
- **Balancing**
- **Sharing**

Gridding



- ALL threats - one reference
- At least four dimensions
- Plan for data integration
- Plan for synthesizing into information

Indexing

- **Normalize the data we can**

- **Weather**
  - Turbulence
  - Icing
  - Approach Conditions
  - Runway Conditions

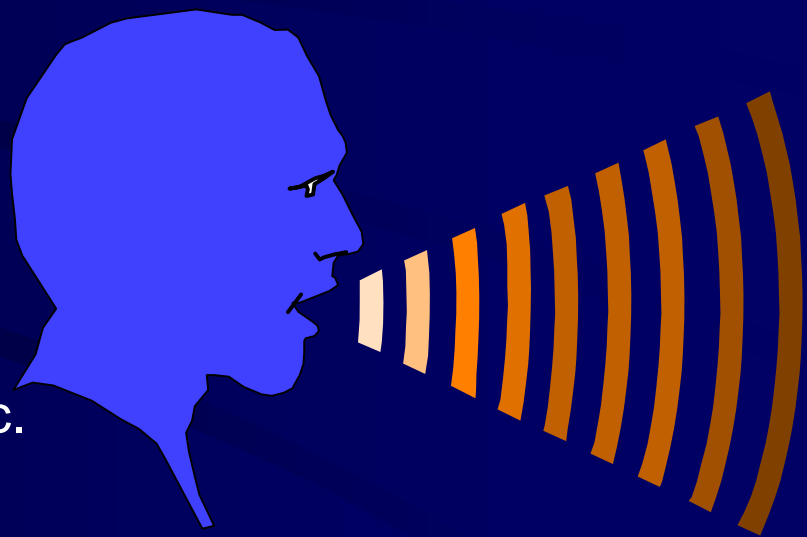
- **Other Threats**
  - Mission
  - Training Level
  - Avionics
  - Airspace
  - Traffic Load… Etc.

"Boeing 777 reports light chop at 5,000 feet on approach" (At 310 knots with a wing loading of 90 #psf…)

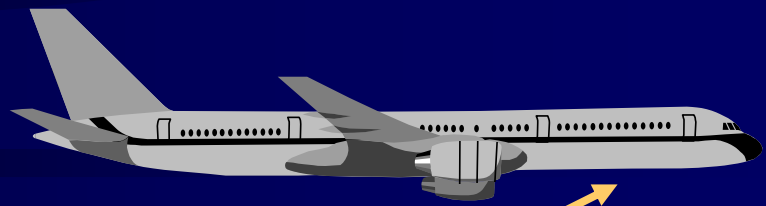
What does that mean to me in my Piper Archer???!!!

Communication Effects

- **Paradigm**
  - % Request/Reply, Ownership, Business model, etc.
- **Transmission**
  - Schemes, Frequencies, etc.
- **Compression**
  - Techniques, Allowances, etc.
- **Transmitter**
  - Location, Density, Ownership, etc.

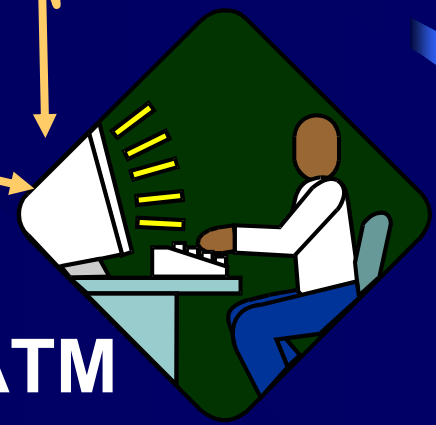


Balancing Capabilities



Airplane

AOC



ATM

Sharing for Optimum Performance

- **We do NOT need**
  - The same “picture” displayed to everyone
- **We DO need**
  - The same “information” *available* to everyone
- **Sharing Reduces Human Tendency to**
  - Second guess, guard, impose
- **Sharing Enhances Tendencies to**
  - Trust, cooperate, be safe

Beware the Liability Gap!

- **Next 36 months are critical**
- **Information and Communications Explosion**
- **A Critical Event Will Force:**
  - Rapid Equipage
  - Ad Hoc “Standards”
  - Frozen Standards
  - Limited Growth

Outline

Roger Herron - LM Aero

- Non-aviation Communications - Potential Wx Solutions

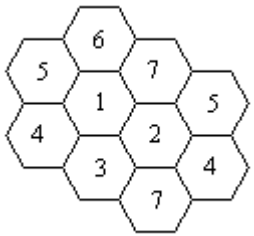
Non-Aviation Solutions

- **Purpose:**
  - *"Identify and evaluate specific existing communications technologies, techniques and services which could offer potential technical solutions enabling the efficient delivery and use of tactical and strategic weather data and tools." SOW*
- **Non-Aviation Communications / Technology**
  - Cellular / PCS Telephone Technology
  - MMDS / LMDS
  - Satellite - Digital Audio Radio Services (S-DARS)
  - Internet in/from the Sky
  - Software Defined Radios

Cellular Phone Concepts

The Cell

- A frequency re-use pattern
- Based on seven cell pattern
- Cell radius: 0.6 to 30 Miles



7 cell re-use pattern

Extended re-use

Tracking / Hand-off

- Caller identification/billing
- Switching
- Location/Tracking
- Cell to Cell hand-off

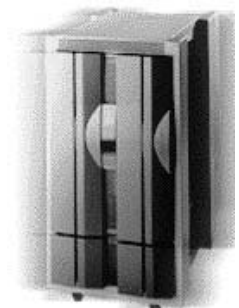
Mobile Unit

Antenna & Base Station

To Other MSCs

Mobile Switching Center (MSC)

To PSTN



Call Processing
- Authentication Center (AC)
- Home Location Register (HLR)
- Visitor Location Register (VLR)
- Equipment Identify Register (EIR)

Cellular / PCS Phone Standards

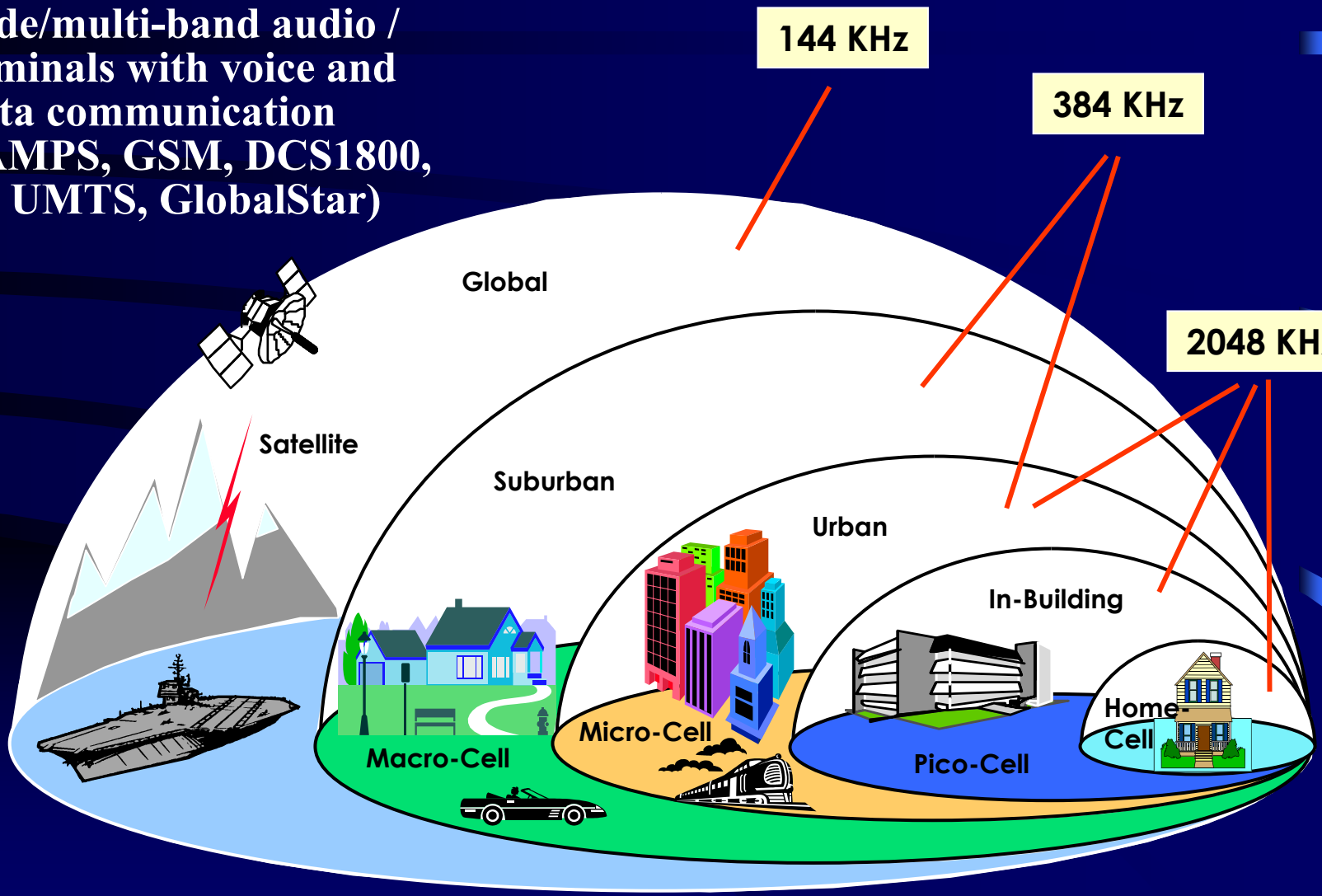
- **First generation (analog)**
  - AMPS (Advanced Mobile Phone Service): **Analog system introduced in 1983. TIA Standard IS-41.**
  - N-AMPS (Narrowband AMPS): **1/3 bandwidth, 3x channels**
- **Second generation (digital)**
  - D-AMPS (Digital AMPS) : **TDMA implementation using same frequency and control system as AMPS. TIA Standard IS-54.**
  - CDMA (Code Division Multiple Access): **TIA Standard IS-136**
  - GSM (Global System for Mobile Communications): **Standard used throughout Europe.**
- **Personal Communication Systems (PCS)**
  - DCS1800: **1.8 GHz version of GSM used in Europe**
  - PCS1900: **North American version of GSM operating at 1.9 GHz**
  - Also upbanded AMPS, N-AMPS, D-AMPS, CDMA

Cellular / PCS Extensions and Variations

- **LEO/MEO Satellite Systems**
  - Iridium: **GSM compatible - existing GSM customers can insert their SIM card into the Iridium phone and access the Iridium satellite network**
  - GlobalStar: **User Terminals: dual or multi-mode (AMPS, GSM, PCS1900). First try to connect through existing cellular networks, failing that, connect through satellite system.**
  - ICO: **Most ICO phones will be similar in size and appearance to standard cellular phones and will be capable of dual-mode (satellite and GSM / AMPS / D-AMPS) operation.**
- **Airborne Cellular Telephone**
  - AIRCELL: **December 1998 FCC approved "*waiver*" to operate on same 800 MHz - but on a secondary basis - decision based on recommendations from NTSB, FAA, NBAA, AEA, AOPA**
- **Third Generation (future)**
  - UMTS (Universal Mobile Telephone System) **European led initiative to define the next generation of global cellular - expected by 2004**

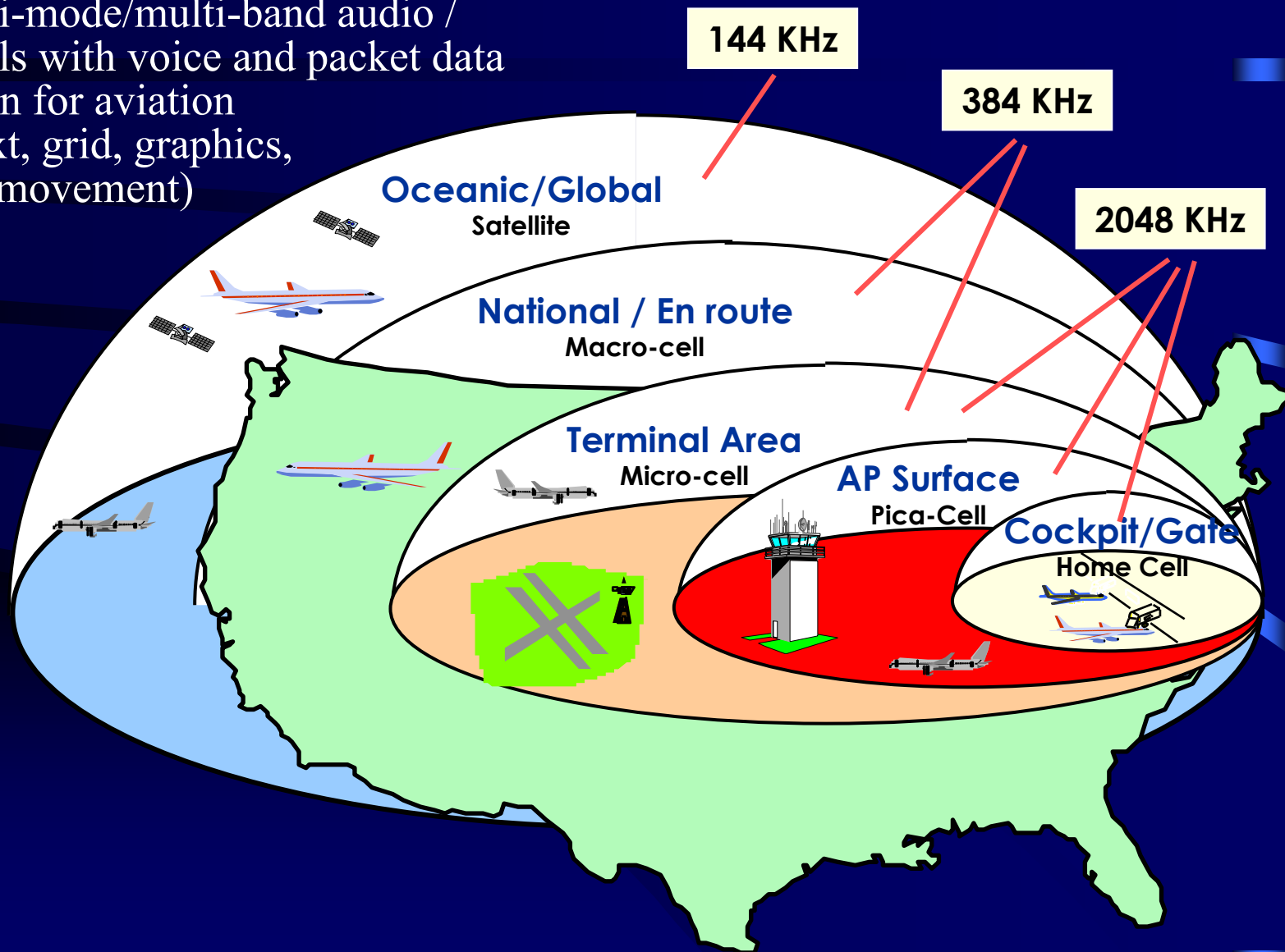
UMTS Seamless End-to-End Service

Multi-mode/multi-band audio / visual terminals with voice and packet data communication (DETC, AMPS, GSM, DCS1800, PCS1900, UMTS, GlobalStar)



Aviation Implementation of UMTS ???

Aviation Multi-mode/multi-band audio / visual terminals with voice and packet data communication for aviation Wx (voice, text, grid, graphics, animated Wx movement)



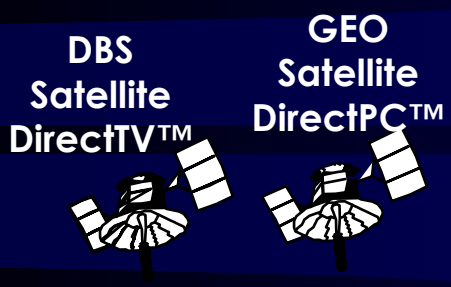
Needed Technology / Benefits

- **New Technology Needed**
  - Digital will likely replace analog cell phones - not clear what effect this will have on future of airborne cellular.
  - Extension of *digital* cell phone technologies for aviation applications (interference, power levels, multiple access- CDMA?)
  - Multimode airborne receivers (GSM, PCS1900, LEO/MEO) to interoperate between cell and Satcom, voice and digital applications
- **Benefits**
  - Maintain current GA benefits of airborne cellular technology
  - Expand coverage and reliability of low-cost avionics / services
  - Include aviation in future mobile communications, i.e. UMTS

Teledesic - Internet-in-the-Sky™

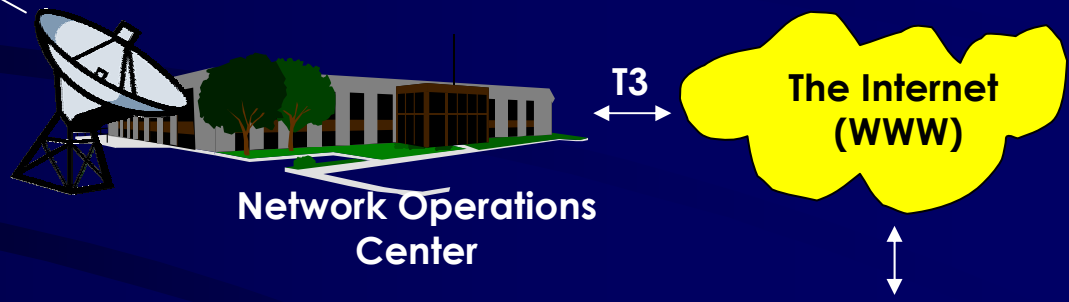
- **A broadband satellite network to provide "fiber-like" access to telecommunication services world-wide**
  - Applications: **Broadband internet access, interactive multimedia, and high quality voice.**
  - Usage cost: **Expected to be competitive with wireline/fiber optic systems.**
  - Availability: **Service to begin in 2004.**
- **Technology**
  - 288 satellites in Low Earth Orbit (LEO)
  - Ka band: **28.6-29.1 GHz Uplink, 18.8-19.3 GHz Downlink**
  - User data rate: **2 mbps uplink, 64 mbps downlink**
  - Designed for Fixed Satellite Services (FSS) - i.e. home/office - but expects to serve marine and aviation customers.
- **Potential Aviation Wx Applications / Issues**
  - Could address communication requirements for all aviation Wx products including voice, text, graphics and gridded data.
  - Components designed for fixed based system operation would have to be adapted for flight deck application - i.e. tracking antenna

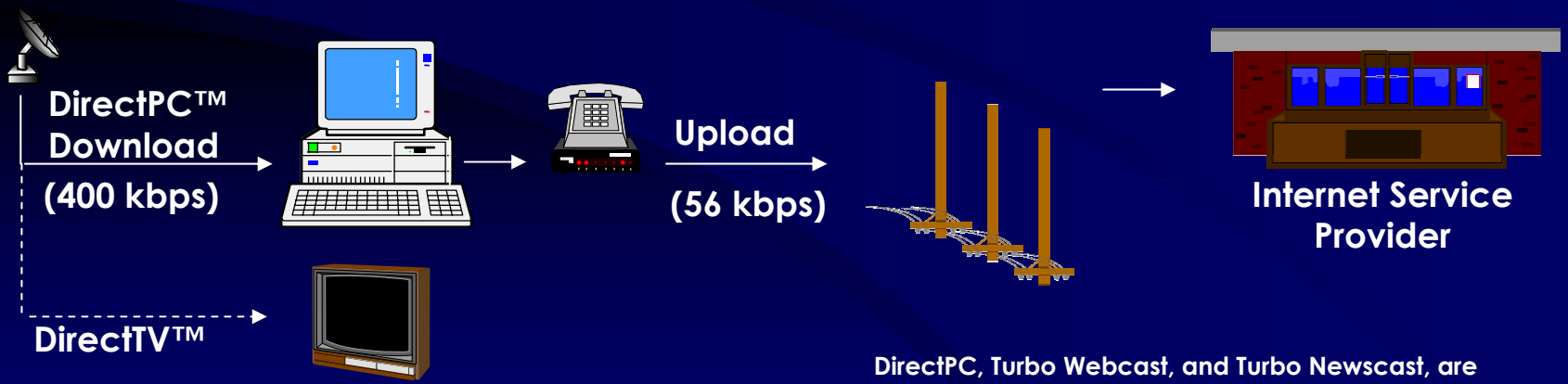
DirectPC™ Internet-from-the-Sky



Turbo Webcast™ / Turbo Newscast™

- 7 to 9 layer deep downloads of specific web sites for offline viewing
- Telephone modem doesn't have to be online
- Download doesn't count against allotment of service hours



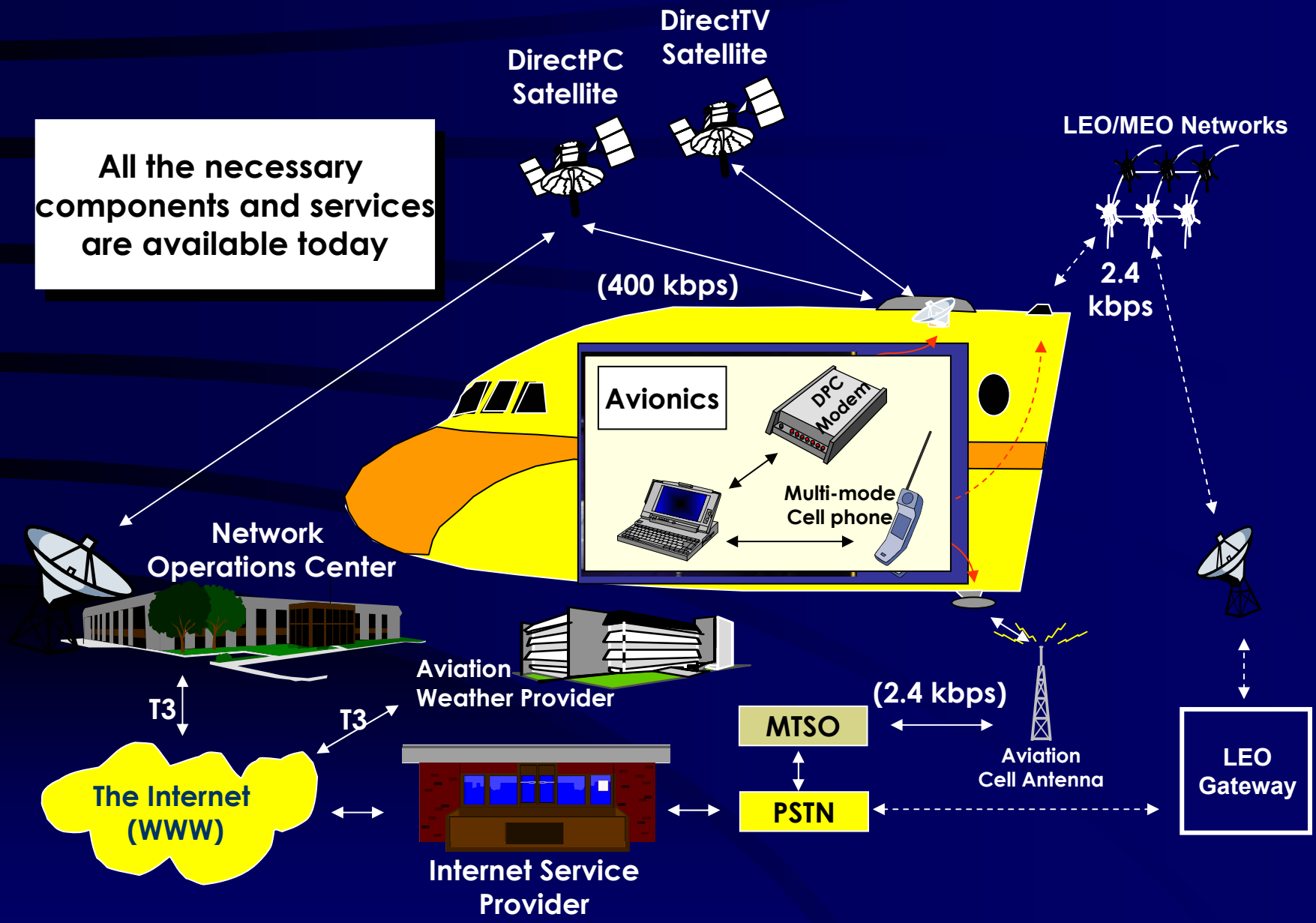


Aviation Direct Broadcast Satellite (DBS) Services

- **LiveTV™ DBS IFE**
  - Part of in-seat entertainment system
  - Compatible with DirectTV™
  - On A320 and 737-400 already
  - DirectPC™ ???
- **Datron Airborne DBS**
  - DBS 2100 and DBS 2400 Airborne Antenna systems
  - Compatible with DirectTV™
  - Certified for use on business jets and large air carriers
  - DirectPC™ ???

Aviation Internet-from-the-Sky

All the necessary components and services are available today



Potential Aviation Wx Application

- **Request/Reply for high volume Wx products**
  - Flight specific weather text & graphics - selected by flight crew
  - GRiB, Radar graphics, etc.
  - Could include automated system to periodically check Wx for updates/alerts (similar to the way e-mail applications check for new e-mail on the server)
- **Technology Needed**
  - System integration, test & certify
  - Wx product packaging / web site design optimized for “bulk” download to flight deck to simplify R/R process
- **Benefit**
  - Nation wide, (soon to be world wide) high data-rate aviation information source - - not limited to Wx applications.
  - Low cost installation and usage (relative speaking)
  - Tripple redundant system with graceful degradition (GEO, Cellular, LEO/MEO)

Software Defined Radios (SDR)

- **What are Software Defined Radios (SDR)?**
  - Radios that can change their frequency, bandwidth and modulation scheme through software programming
- **DoD Initiatives**
  - JTRS is a joint services, family of radios that are interoperable, affordable, & scaleable - with a common open architecture - ability to share waveform software between radios. Plan to migrate all legacy systems to the (Joint Tactical Radio System) JTRS open systems architecture - over 45 systems
- **FCC Interests**
  - Exploring ways to facilitate experimental and commercial deployment of SDR. Begins inquiry regarding software defined radio on March 17, 2000
- **Potential Aviation Applications**
  - Provide same benefit to civil aviation as needed for military, i.e. multi-band, multi-mode, multi-function radios able to adapt to all existing and future voice and datalink aviation communication systems, around the world, through software programming.

Outline

- Project Overview
- Current / Near Term Flight Deck Products/Systems
- Aviation Weather ~ A Pilot's Perspective
- Resulting Human Factors
- Proposed Direction
- Non-aviation Communication Wx Solutions
- Conclusions / Recommendations

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Current Aviation Wx Delivery Systems

- **Voice Wx Products**
  - Currently delivered by a combination of broadcast and 2-way voice radio to FSS / AFSS
  - Some broadcast systems (i.e VORs) may need to be replaced but most are expected to continue alongside data link systems.
- **Text Wx Products**
  - ACARS delivers general Wx from AOCs.
  - Pilots also access Terminal Wx via ACARS
- **Graphics / Gridded Data**
  - Minimal current support

Conclusions~

Aviation Communications Wx Solutions

- **Voice Wx Products**
  - Transition to datalink could mean fewer voice channels. Datalink expected to reduce usage.
- **Text Wx Products**
  - ACARS equipped planes may soon get Wx from ARINC/ARNAV.
  - FIS-B will soon broadcast Wx text & some graphics. Oceanic and remote regions not covered. High altitude still a question.
  - NEXCOM may have limited broadcast capability; however, ATN Wx application elements still need to be developed.

Aviation Communications Wx Solutions

- **Graphics / Gridded Data**
  - The 4 VHF FIS-B frequencies may be inadequate for future Wx products.
  - Users could easily overload NEXCOM by frequent requests for large Graphical/Gridded Wx products.
  - ADS-B may provide Wx support if UAT is successful. VDL4 would be OK enroute, and could work in terminal area with proper “cell” management. Mode-S would be too bandwidth limited.

Non-Aviation Comm Wx Solutions

- **Voice Wx Products**
  - Cell / Sat phones provide request/reply opportunities. Research needed to expand availability.
  - S-DARS has limited potential for aviation Wx voice broadcast.
- **Text Wx Products**
  - Cell / Sat phones, FAX, and Internet could provide access to text and some graphic products from FSS / AFSS or the World Wide Web.

Non-Aviation Comm Wx Solutions

- **Graphics / Gridded Data**
  - Limited request/reply availability using Cell/Sat phones to access internet aviation weather sites. Bandwidth limitations may prevent widespread usage.
  - Future cell phone technologies could address needs if aviation is included.
  - Large graphic & gridded files could be delivered using a combination of DirectPC & Cell/Sat phone technology.
  - Future Internet-in-the-Sky™, could address a wide range of aviation communication needs - airborne mobile technology needs further development
  - Software Defined Radios could be developed for civil aviation use

Overall

- **Bandwidth required for “cockpit” applications will be dwarfed by demand for passenger entertainment and services - we should take advantage of the available resources where possible**

- **There is a significant opportunity for timely investment in moderate-risk/high-payoff research**

Overall

- **Wide-band systems may make the notion of frequency allocation obsolete**
- **AWIN is the right application to stimulate initial development of the modern digital systems needed**

All Comm Wx Solutions

- **Work toward industry unity in**
  - Understanding / adopting the Phase I concepts
  - Indexing all appropriate hazards, not just weather
  - Gridding all hazards in a common 4D manner
  - Developing link independent message formats with indexing & gridding in mind
  - Maximizing compression with these message formats

Recommendations~

Aviation Communications Wx Solutions

- **Aggressively participate in determining the definition and fallout of “Tactical” weather**
- **Predict the appropriate mix of addressed and broadcast weather products**
- **Create intelligent boundaries among varying neighboring areas of regard, transmitters, and datalinks**
- **Prepare to capitalize on the ADS-B link decision**

Non-Aviation Communications Wx Solutions

- Develop digital cell phone technology for aviation applications (interference, power levels, multiple access)
- Develop aviation multimode receiver technology to interoperate between cell and satcom, voice and digital
- Develop avionics system combining cell/sat phones and satellite internet for Wx delivery, integrate & test
- Work with Wx providers and/or FAA (ADDS) to structure aviation weather web site optimized for "bulk" download to flight deck.
- Investigate civil applications for Software Defined Radios

Overall

- Leverage passenger entertainment internet applications for cockpit use in both the technical and political arenas
- Lead an effort to move aviation from a frequency allocation to a bandwidth allocation paradigm
- Use AWIN and the “liability gap” as leverage to develop the digital systems, certification, and concepts needed to ensure modern communications are available to the cockpit.

Questions?